Report No. NAWCADWAR-93082-60

(1)

AD-A283 207

EVALUATION OF ALTERNATE F-14 WING LUG COATING

Janet L. McGovern and Alan E. Ankeny
Air Vehicle and Crew Systems Technology Department (Code 6061)
NAVAL AIR WARFARE CENTER
AIRCRAFT DIVISION WARMINSTER
P.O. Box 5152
Warminster, PA 18974-0591

1 December 1993

FINAL REPORT
Period Covering 1 January 1991 To 30 September 1993

Approved for Public Release; Distribution is Unlimited

Prepared for
Naval Air Systems Command (Air-5116B)
Arlington, VA 22243-4530

NOTICES

REPORT NUMBERING SYSTEM — The numbering of technical project reports issued by the Naval Air Warfare Center, Aircraft Division, Warminster is arranged for specific identification purposes. Each number consists of the Center acronym, the calendar year in which the number was assigned, the sequence number of the report within the specific calendar year, and the official 2-digit correspondence code of the Functional Department responsible for the report. For example: Report No. NAWCADWAR-92001-60 indicates the first Center report for the year 1992 and prepared by the Air Vehicle and Crew Systems Technology Department. The numerical codes are as follows:

CODE	OFFICE OR DEPARTMENT
00	Commanding Officer, NAWCADWAR
01	Technical Director, NAWCADWAR
05	Computer Department
10	AntiSubmarine Warfare Systems Department
20	Tactical Air Systems Department
30	Warfare Systems Analysis Department
50	Mission Avionics Technology Department
60	Air Vehicle & Crew Systems Technology Department
70	Systems & Software Technology Department
80	Engineering Support Group
90	Test & Evaluation Group

PRODUCT ENDORSEMENT — The discussion or instructions concerning commercial products herein do not constitute an endorsement by the Government nor do they convey or imply the license or right to use such products.

Reviewed By: J F Ohlson Date: 6 Jun 94
Branch Head

Reviewed By: ______ Date: ______
~~Division Head~~

Reviewed By: [signature] Date: 6/11/94
Director/Deputy Director

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	1 DEC 1993	Final 1 JAN 91 – 30 SEP 93

4. TITLE AND SUBTITLE

EVALUATION OF ALTERNATE F-14 WING LUG COATING

5. FUNDING NUMBERS

6. AUTHOR(S)

Janet L. McGovern and Alan E. Ankeny

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Air Vehicle and Crew Systems Technology Department (Code 6061)
NAVAL AIR WARFARE CENTER
AIRCRAFT DIVISION WARMINSTER
P.O. Box 5152
Warminster, PA 18974-0591

8. PERFORMING ORGANIZATION REPORT NUMBER

NAWCADWAR-93082-60

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Naval Air Systems Command
Air-5116B
Arlington, VA 22243-4530

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for Public Release; Distribution is Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The F-14 wing lug is coated with specific formulation polyurethane coating which prevents scoring of the wing lug by providing a wear surface for the outside diameter of the wing pivot bearing. The manufacture of this coating material was discontinued in 1991 because the original formulation used talcs which contained asbestos as impurities. The new formulation, containing asbestos free talcs, was inadequate in providing the abrasion resistance required to protect the F-14 wing lug. A new coating or coating process was required. A centrifugation processing procedure for the new formulation was developed which appeared to provide a coating that exhibited similar wear characteristics as the original coating. Oscillation wear tests were required to determine bearing wear performance of the alternate coating under normal and high stress in both the dry and fluid contaminated states.

Constant speed/constant load wear tests were performed on sample parts for both the original and alternate coatings. The result indicate that there is no significant difference in the performance of the two coatings. Based on the satisfactory results of the laboratory tests, approval of the alternate coating and the centrifugation process is recommended. The coating should be applied by spraying several thin coats until a thickness of 0.8 to 1.5 mils is achieved.

14. SUBJECT TERMS

F-14 Wing Lug Wing Pivot Bearing Coating

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

Contents

Figures

Tables

Acknowledgments

The authors wish to acknowledge and thank those who provided technical assistance with the performance of tests and inspections in this project; Mr. Don Hirst and Mr. John Dietzel of the Materials Protection Branch for performance of the Taber Abraser tests and preparing the polyurethane coated sleeves; Mr. Vince Novielli, Mr. Malio Ventresca and Mr. Greg Auxer of the Materials Application Branch for performance of the oscillation wear test; and Mr. Walt Mahaffey of the Naval Aviation Depot-Norfolk for providing polyurethane coated sleeves.

SUMMARY

The F-14 wing lug is coated with a specific formulation polyurethane coating. This coating prevents scoring of the wing lug by providing a wear surface for the outside diameter of the wing pivot bearing. The manufacture of this coating material was discontinued in 1991 because the original formulation used talcs which contained asbestos as impurities. The new formulation, containing asbestos free talcs, was inadequate in providing the abrasion resistance required to protect the F-14 wing lug. A new coating or coating process was required.

The Naval Air Warfare Center-Aircraft Division Warminster (NAWCADWAR) developed a centrifugation processing procedure for the new formulation which appeared to provide a coating that exhibited similar wear characteristics as the original coating. Oscillation wear tests were required to determine bearing wear performance of the alternate coating under normal and high stress in both the dry and fluid contaminated states.

Constant speed/constant load wear tests were performed on sample parts for both the original and alternate coatings. The coatings were tested with both the Kahr Bearing X1200S and X1461 liners used in the F-14 wing pivot bearing. The results indicate that there is no significant difference in the performance of the two coatings when subjected to oscillation wear tests in the dry condition or when subjected to hydraulic fluid contamination for one hour prior to testing. Tests also indicate that the coating application must be thick enough to achieve the desired wear characteristics of the wing pivot bearing and protection of the wing lug. The thickness of 0.8 to 1.5 mils specified in the Naval Aviation Depot-Norfolk (NADEPNORVA) F-14 Local Engineering Specification (LES) has been satisfactory in the past and therefore continues to be the recommended thickness.

Based on the satisfactory results of the laboratory tests, approval of the alternate coating and the centrifugation process is recommended. The coating should be applied by spraying several thin coats until a thickness of 0.8 to 1.5 mils is achieved.

INTRODUCTION

The F-14 wing lug is coated with a specific formulation of DeSoto Chemical Company's MIL-C-27725 polyurethane fuel tank sealant. This coating provides the wear surface for the outside diameter of the Wing Pivot Bearing (WPB) and consequently prevents scoring of the wing lug which could lead to failure of the wing. This coating was originally developed for sealing and corrosion protection in aircraft integral fuel tanks. To achieve the desired wear characteristics for the wing lug surface, a processing technique was developed for the coating which allowed the pigments to partially settle, forming a resin rich top layer. This resin rich portion is used to coat the F-14 wing lugs.

The original coating formulation included talcs which contained 0.1% and 2% asbestos as impurities. The asbestos impurities caused production of these talcs to be discontinued in 1991. As a result DeSoto was forced to substitute asbestos free talcs. The new formulation resulted in a coating which exhibited less pigment settling when mixed and less abrasion resistance when applied. A new coating material or new coating process was required to maintain wear protection of the F-14 wing lug.

The NAWCADWAR investigated several alternatives. Preliminary results indicated that an alternate DeSoto coating subjected to a forced pigment sedimentation (accomplished by a centrifugation processing procedure specified in Appendix A) exhibited superior wear characteristics as well as acceptable adhesion, flexibility, fluid resistance, and hardness properties (see Report No. NAWCADWAR-92045-60 dated 15 February 92). Further tests were required to determine the bearing wear performance of the alternate coating under normal and high stress conditions in both the dry and fluid contaminated states.

METHODS, ASSUMPTIONS AND PROCEDURES

To evaluate the performance of the new formulation wing lug coating, various tests were performed on sample parts with the original coating and with the new formulation coating. In this report, the original coating material and its associated processing procedure (specified in NADEP NORVA F-14 LES, NO(35) 6921, paragraph 7) will be referred to as Coating I. The new formulation and its processing procedure (specified in Appendix A) will be referred to as Coating II.

Taber Abraser tests were performed in accordance with ASTM 4060 to evaluate the abrasive wear resistance characteristics of Coating I and Coating II. Test panels were cleaned to remove surface film and then coated with Coating I and Coating II. The same cure and bake cycle was used as for the wing lug. The surface of the panel was abraded by rotating the panel under a 1000 gram load using CS-17 abrasive wheels. Results were determined by measuring weight loss per 1000 revolutions. The average values of three or more tests were recorded and are shown in Table I.

To evaluate the bearing wear performance of the alternate wing lug coating, constant load/constant speed oscillation wear tests were performed on sample parts. The F-14 wing lug surface was simulated using a titanium sleeve coated with polyurethane on the outer diameter. The titanium sleeve was bonded to a 0.750 inch stainless steel shaft to facilitate installation in the test machine. The WPB surface was simulated with a stainless steel bearing with the liner bonded to the inner diameter (see Appendix B).

The bearing was installed in a steel housing, using a 0.0001 to 0.0005 inch clearance fit, with a test shaft installed in the bore. The fit between the bearing and test shaft was recorded. The bearing was installed so that the test shaft was placed in double shear. A dial indicator was mounted on top of the housing so that any wear of the coated

test shaft or bearing could be measured. The specified load was applied and held statically for 15 minutes. At the end of this time, the dial indicator was set at zero and the oscillating test was started. The pin was oscillated at ±25 degrees at 20 cycles per minute. One cycle consisted of rotation from zero degrees to +25 degrees, return through zero to -25 degrees and return to zero degrees (for 100 degrees of total travel). Wear readings were taken at the second cycle and then periodically throughout the test. The second cycle reading was the zero (reference) reading. The tests were run to 100,000 cycles or 0.0040 inch indicated wear, whichever occurred first. Tests were discontinued prior to 100,000 cycles or 0.0040 inch wear if there was a sudden rise in indicated wear in order to prevent metal to metal contact.

Initial tests were performed using 1.000 inch inner diameter (ID) by 0.500 inch long bearing lined with Kahr X1200S liner. These parts were subjected to 16,000 pounds of unidirectional load resulting in 45 ksi of stress (see Appendix C). Three test shafts were coated with Coating I by NADEPNORVA and three tests shafts were coated with Coating II by NAWCADWAR. These shafts were subjected to the test parameters listed above and the results listed in Tables 2 and 3. To generate data on fluid contaminated bearings the shafts and bearings were soaked in MIL-H-83282 hydraulic fluid for one hour. The shafts and bearings were removed from the fluid and reinstalled in the test machine so that the orientation of the load was 180° from the original test and the test was repeated. The data with fluid contamination are reported in Tables 4 and 5.

To achieve the maximum stress level of 69.4 ksi specified in the Grumman 9/9A test the bearing length was reduced to 0.380 inch long and the load was increased to 18,000 pounds (see Appendix C). Eighteen bearings were lined with X1200S liner and fourteen were lined with X1461 liner. Initially, fourteen test shafts were coated with Coating I by NADEPNORVA, twelve were coated with Coating II by NAWCADWAR and six were coated with Coating II by NADEPNORVA. These shafts were subjected to the test conditions listed above for both the dry and the MIL-H-83282 hydraulic fluid contamination tests. Results of the dry 69.4 ksi tests on X1200S liner are shown in Tables 6 and 7. The hydraulic contamination tests are shown in Tables 9, 10 and 11. Results of the dry 69.4 ksi tests on X1461 liner are shown in Tables 12 and 13 and the hydraulic contamination tests are shown in Tables 14 and 15. Subsequently NADEPNORVA coated three more shafts with Coating II. The shafts (numbers 62, 63 and 64) and three bearings lined with X1200S were first subjected to the dry 69.4 ksi test. They were then removed from the test machine and, following a one hour soak in hydraulic fluid, the parts were reinstalled so that the orientation of the load was 180° from the original test and the test was repeated. The results of these tests are shown in Tables 8 and 11.

RESULTS AND DISCUSSION

The results of the Taber Abraser tests indicate that there is no significant difference in the abrasion resistance of Coating I and Coating II. There is a difference in

Figure 1. Indicated wear for 45 ksi test for Coating I versus X1200S liner, dry condition.

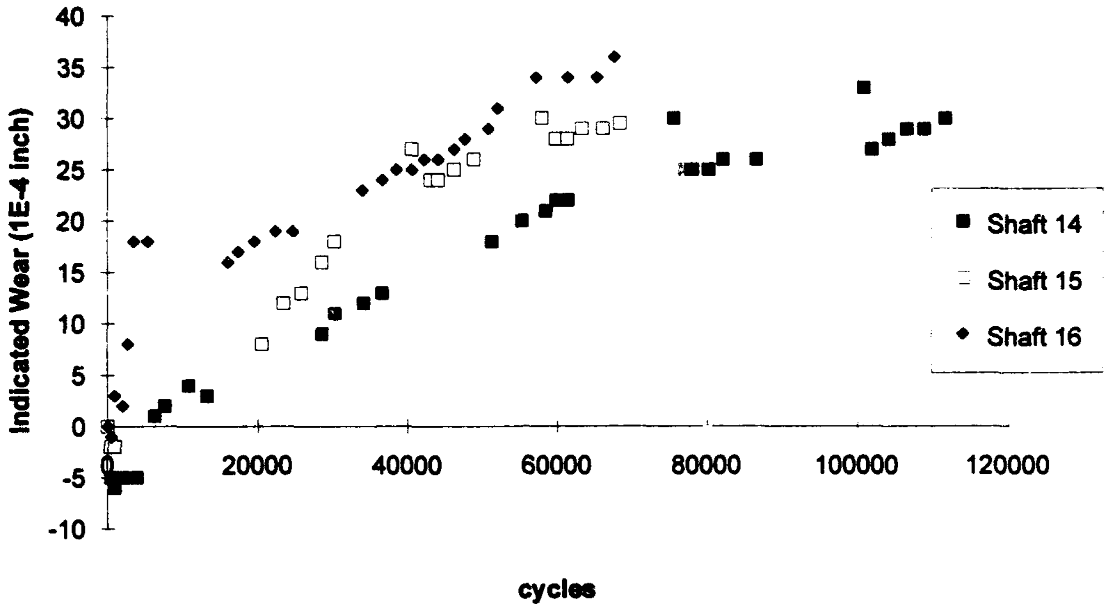
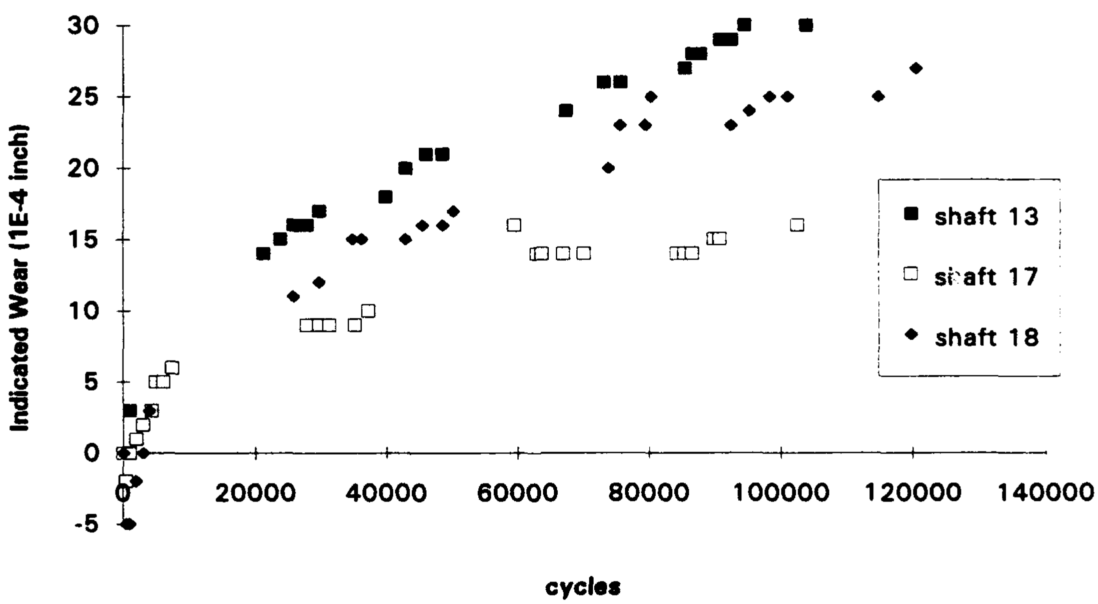


Figure 2. Indicated wear for 45 ksi test for Coating II versus X1200S liner, dry condition.



Test shaft and bearing specimens were re-used for the hydraulic contamination test because of time constraints. The results of these tests, shown in Tables 4 and 5, indicate that there is no significant difference in the performance of the two coatings when subjected to hydraulic fluid contamination. The wear curves of figure 3 indicate that shaft 14 and 15 assemblies coated with Coating I experienced a constant increase in wear while shaft 16 underwent a sharp increase in wear until about 8000 cycles and then leveled off. The wear curves of figure 4 show that each of the three assemblies with shafts coated with Coating II performed differently. The shaft 13 assembly experienced a constant wear rate, much like that of the shaft 17 assembly, until 50,000 cycles where there was a sudden increase from 0.0027 inch to 0.0091 inch. The test of shaft 18 was discontinued prior to 10,000 cycles because there was a sharp rise in indicated wear. Both coatings were still in good condition, in most cases it was the bearing that failed and not the coating. Bearing failure may have been partly due to the fact that the bearings had already been subjected to 100,000 cycles of testing on the opposite side of the bearing.

Table 4. Results of 45 ksi Oscillation Wear Tests for Coating I versus X1200S Liner with fluid contamination.

Test Shaft Number	Fit Between Bearing and Test Shaft (in)	Sanded (yes or no)	Total Wear (in)	Total Cycles Completed
14	--	yes	0.0047	54,300
15	--	yes	0.0039	45,600
16	--	yes	0.0032	21,500

Table 5. Results of 45 ksi Oscillation Wear Tests for Coating II versus X1200S Liner with fluid contamination.

Test Shaft Number	Fit Between Bearing and Test Shaft (in)	Sanded (yes or no)	Total Wear (in)	Total Cycles Completed
13	--	yes	0.0091	50,950
17	--	yes	0.0034	55,600
18	--	yes	0.0035	9910

Figure 3. Indicated wear for 45 ksi test for Coating I versus X1200S liner with fluid contamination.

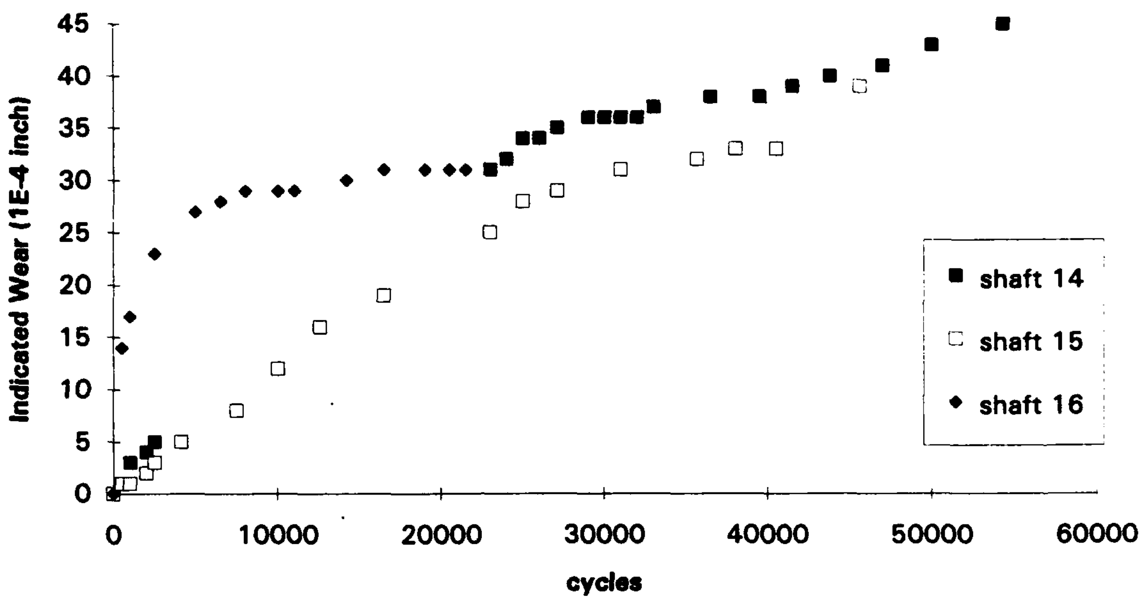
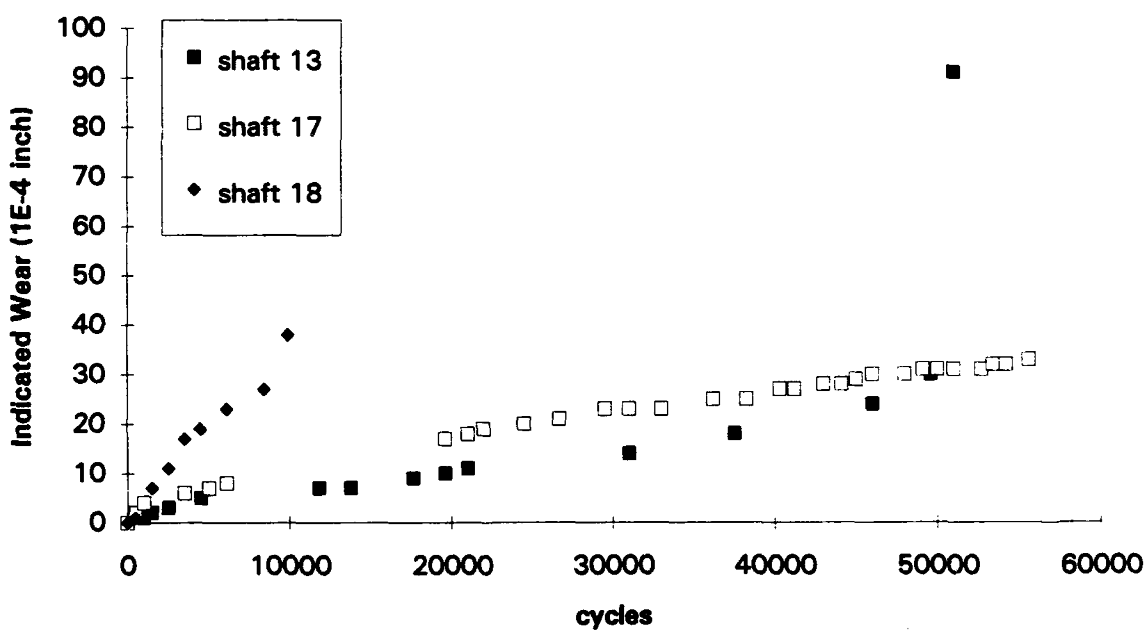


Figure 4. Indicated wear for 45 ksi test for Coating II versus X1200S liner with fluid contamination.



Results of the dry 69.4 ksi stress tests using the X1200S liner, shown in Tables 6 and 7, indicate no significant difference between the performance of the shafts coated with Coating I and with Coating II applied by NAWCADWAR. The wear curves of figures 5 and 6 also indicate no significant difference in the performance of the coatings. Shaft number 27, which completed the most cycles, was the only shaft in which the coating began to peel off. In the other specimens the liner in the test bearing exhibited significant wear while the coating remained in good condition. The three shafts constructed with Coating II exhibited slight scratching in the load area. This may have been caused by liner wear debris abrading the coating surface.

Table 6. Results of 69.4 ksi Oscillation Wear Tests for Coating I versus X1200S Liner, Dry Condition.

Test Shaft Number	Fit Between Bearing and Test Shaft (in)	Sanded (yes or no)	Total Wear (in)	Total Cycles Completed
27	0.0002	yes	0.0035	77,500
32	0.0004	yes	0.0040	52,400
33	0.0002	yes	0.0035	32,100

Table 7. Results of 69.4 ksi Oscillation Wear Tests for Coating II applied by NAWCADWAR versus X1200S Liner, Dry Condition.

Test Shaft Number	Fit Between Bearing and Test Shaft (in)	Sanded (yes or no)	Total Wear (in)	Total Cycles Completed
37	0.0008	yes	0.0035	29,900
38	0.0005	yes	0.0036	32,500
39	0.0012	yes	0.0035	68,800

Figure 5. Indicated wear for 69.4 ksi test for Coating I versus X1200S liner, dry condition.

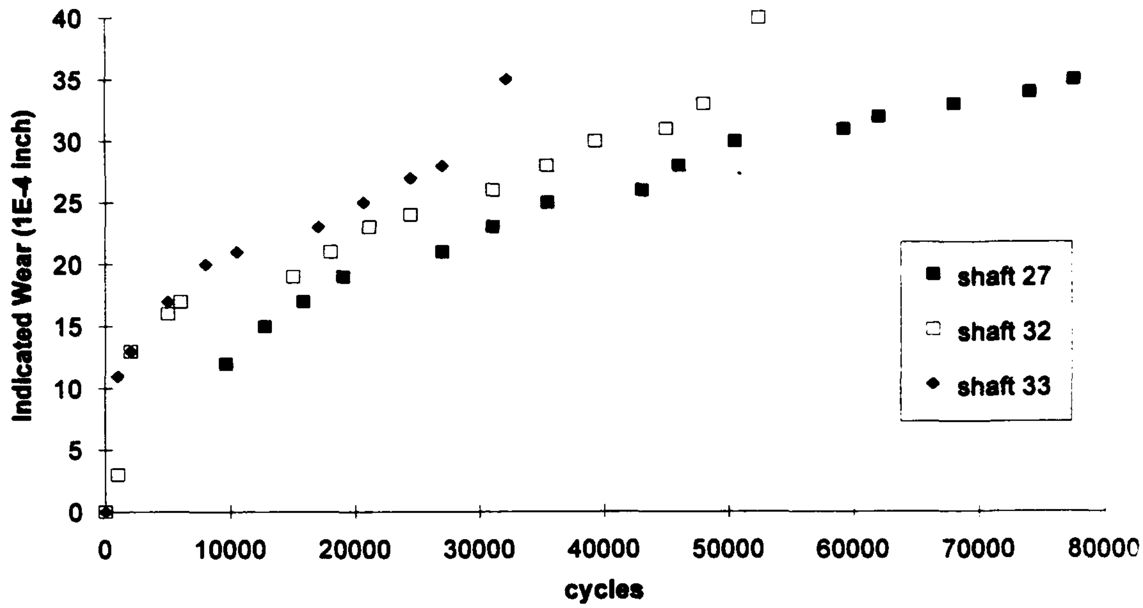
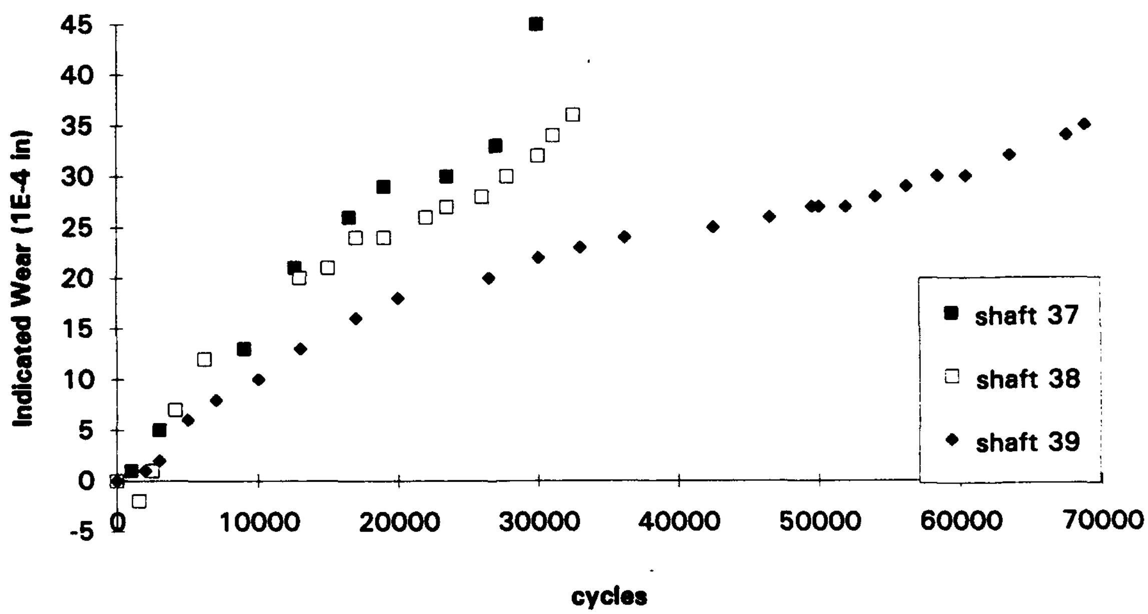


Figure 6. Indicated wear for 69.4 ksi test for Coating II versus X1200S liner, dry condition

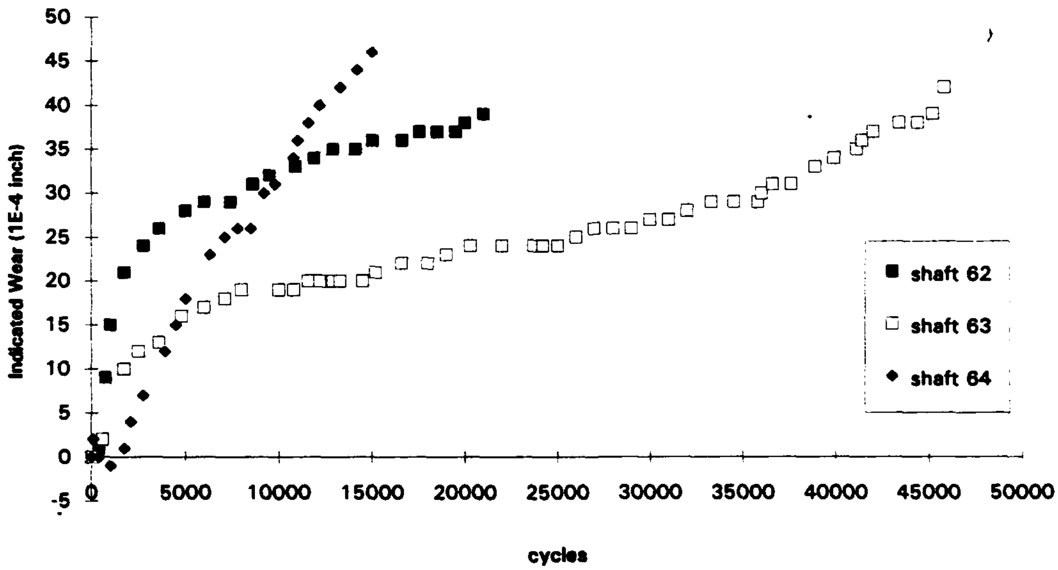


Results of Table 8 indicate that shafts coated with Coating II by NADEPNORVA were unable to complete as many cycles as shafts coated with Coating I or those coated with Coating II by NAWCADWAR. The wear curve of figure 7 indicates that wear occurred at a faster rate than the wear curves of figures 5 and 6. The shafts 62, 63, and 64 contained slight scratching in the wear areas. The X1200S liner wore around the edges in the assembly with shaft 62, 63 and 64. The bearing liner used in conjunction with shaft 62 remained in good condition.

Table 8. Results of 69.4 ksi Oscillation Wear Tests for Coating II applied by NADEPNORVA versus X1200S liner, Dry Condition.

Test Shaft Number	Fit Between Bearing and Test Shaft (in)	Sanded (yes or no)	Total Wear (in)	Total Cycles Comp'
62	0.0019	no	0.0039	21,0[illegible]
63	0.0021	no	0.0042	45,800
64	--	no	0.0046	15,000

Figure 7. Indicated wear for 69.4 ksi tests for Coating II applied by NADEPNORVA versus X1200S liner, dry condition.



Assemblies with Coating II, applied by NAWCADWAR, were able to complete more cycles than assemblies containing Coating I in 69.4 ksi tests on X1200S liner with fluid contamination (Tables 9 and 10). The wear curves of assemblies with Coating I shown in figure 8 show that these assemblies wore at a significantly greater rate than the assemblies with Coating II shown in figure 9. Shaft numbers 24, 25, and 34 which were constructed with Coating I, appeared in good condition with only light scratching on the

surface. There was significant wear in the X1200S liner. Shaft number 36, coated with Coating II by NAWCADWAR, was in good condition. Shaft number 40 contained significant scratching in the load area caused probably by abrasion from the X1200S liner.

Table 9. Results of 69.4 ksi Oscillation Wear Tests for Coating I versus X1200S Liner with fluid contamination.

Test Shaft Number	Fit Between Bearing and Test Shaft (in)	Sanded (yes or no)	Total Wear (in)	Total Cycles Completed
24	0.0003	yes	0.0035	4600
25	0.0006	yes	0.0035	6400
34	0.0008	yes	0.0035	11,800

Table 10. Results of 69.4 ksi Oscillation Wear Tests for Coating II versus X1200S Liner with fluid contamination.

Test Shaft Number	Fit Between Bearing and Test Shaft (in)	Sanded (yes or no)	Total Wear (in)	Total Cycles Completed
35	0.0006	yes	0.0035	85,500
36	0.0007	yes	0.0036	50,400
40	0.0006	yes	0.0035	73,900

Figure 8. Indicated wear for 69.4 ksi test for Coating I versus X1200S liner with fluid contamination.

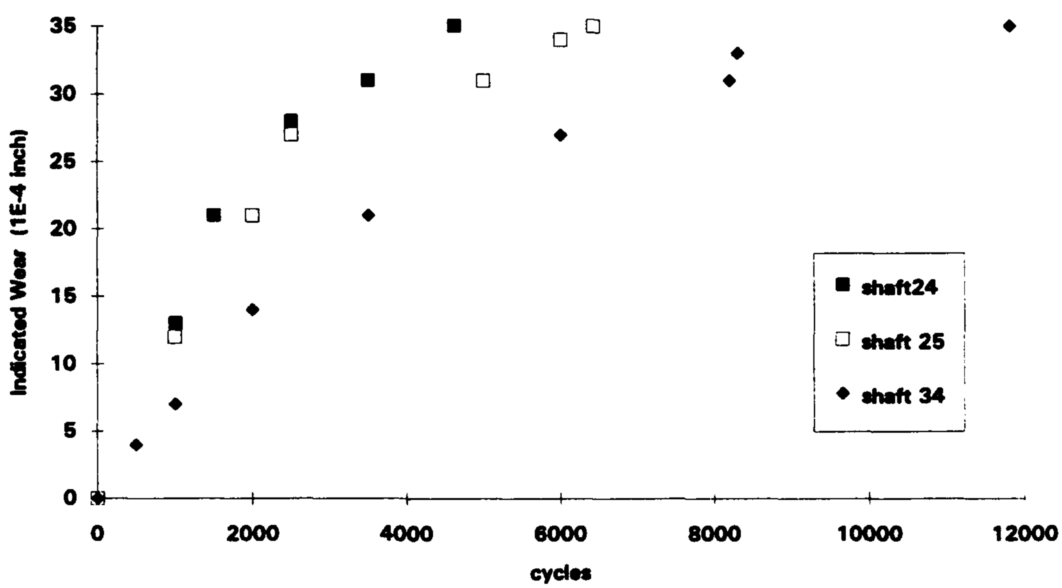
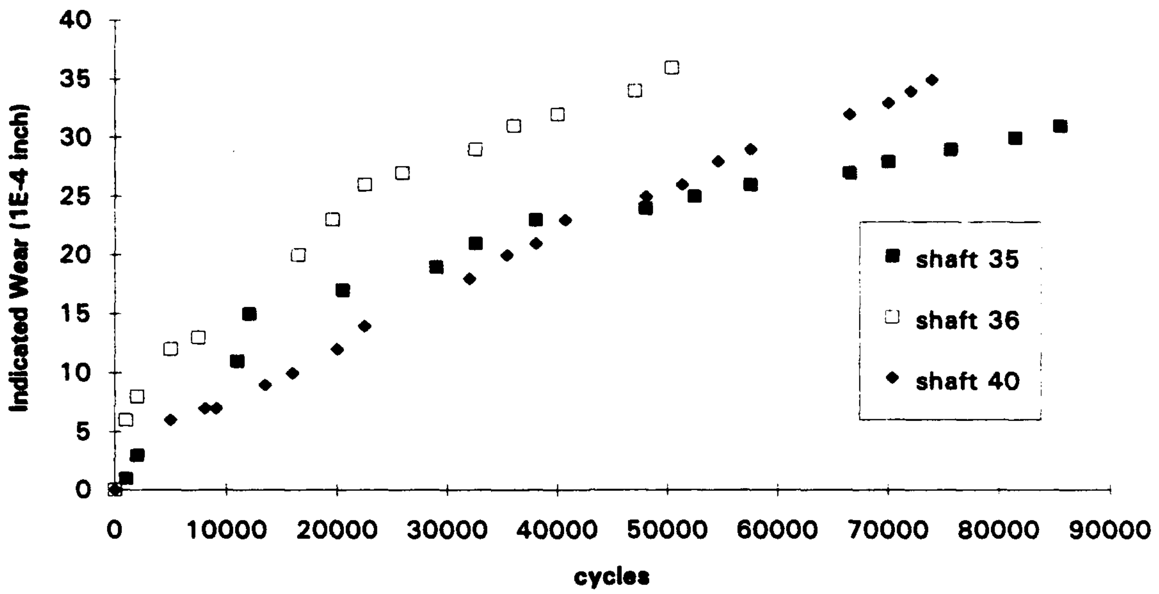


Figure 9. Indicated wear for 69.4 ksi test for Coating II applied by NAWCADWAR versus X1200S liner with fluid contamination.



Comparison of data of Tables 10 and 11 indicates that assemblies constructed with Coating II applied by NADEPNORVA were unable to complete as many cycles as parts coated by NAWCADWAR. The wear rate of assemblies coated with Coating II shown in figures 10 and 10a were much greater than those coated by NAWCADWAR. Comparison of data of Tables 9 and 11 indicates that there is little difference in the performance of Coating I and Coating II applied by the field activity.

Table 11. Results of 69.4 ksi Oscillation Wear Tests for Coating II applied by NADEPNORVA versus X1200S liner with fluid contamination.

Test Shaft Number	Fit Between Bearing and Test Shaft (in)	Sanded (yes or no)	Total Wear (in)	Total Cycles Completed
41	--	no	0.0035	15,500
42	0.0006	no	0.0036	19,400
43	0.0005	yes	0.0035	14,400
44	0.0019	no	metal to metal	14,700
45	0.0018	no	0.0035	25,200
46	0.0018	no	0.0032	37,300
62	--	no	0.0048	2660
63	--	no	0.0038	19,100
64	--	no	0.0049	30,000

Figure 10. Indicated wear for 69.4 ksi tests for Coating II applied by NADEPNORVA versus X1200S liner with fluid contamination.

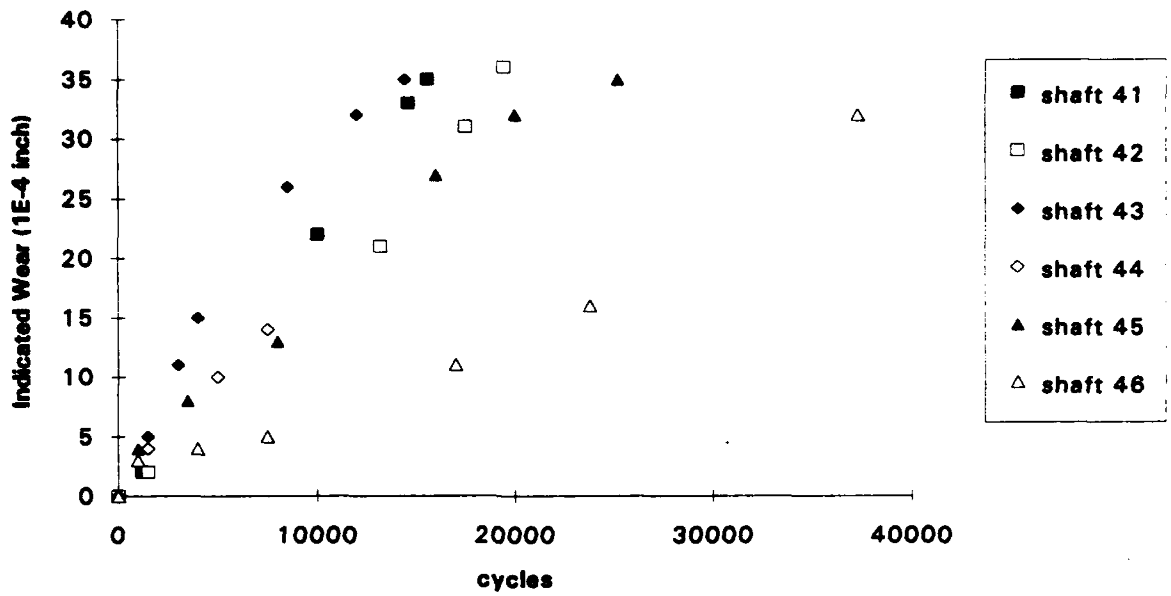
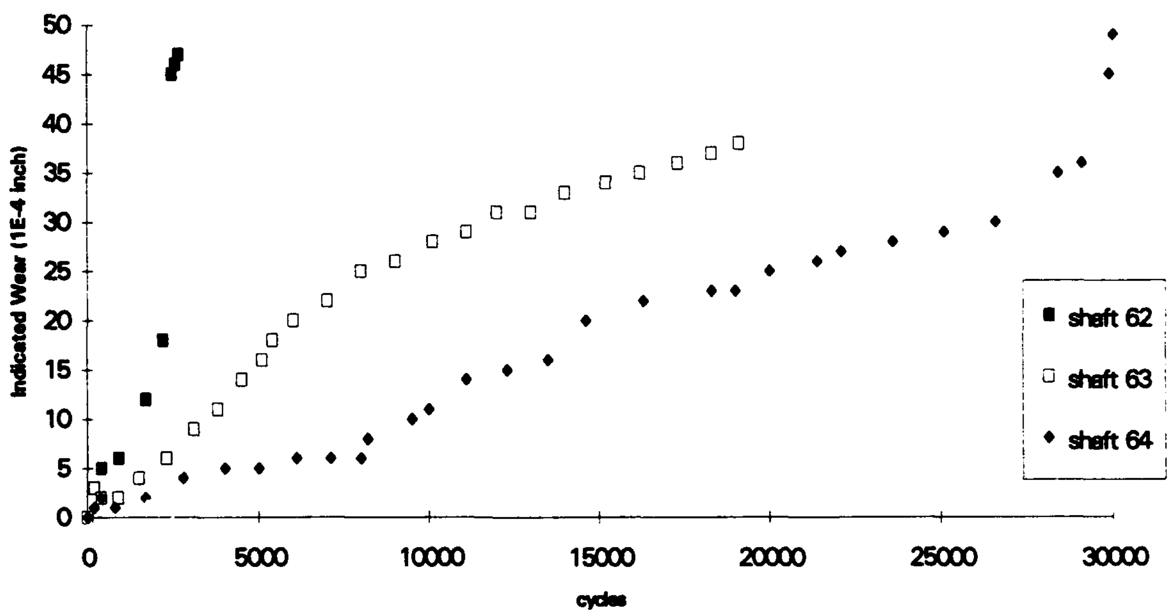


Figure 10a. Indicated wear for 69.4 ksi test for Coating II applied by NADEPNORVA versus X1200S liner with fluid contamination, 2nd application.



The difference in the results of coating performance between the laboratory application by NAWCADWAR and the field application by NADEPNORVA raises several questions. The differences in performance could be caused by the differences in application of the coating, difference in the centrifuge equipment, or batch to batch variation in the coating material itself. The coating applied by the field activity was green while the coating applied by the laboratory was gray-green raising questions as to the consistency of the formulation. (There was a formulation lock on Coating I supplied by DeSoto, this is not necessarily the case with Coating II.) Finally, a difference in the rotation arm length and speed of the centrifuge could cause a difference in pigment settling and subsequently in coating performance.

Results of tests of the X1461 liners, listed in Tables 12 through 15, exhibited significantly more wear in the bearing liner early in the test. The wear curves shown in figures 11 through 14 indicate little difference in wear rate for assemblies with Coating I and Coating II. There was much more after test liner debris in the bearings constructed with the X1461 liner than those constructed with X1200S liner. The shafts subjected to the dry 69.4 ksi tests with X1461 liner, Tables 12 and 13, appeared in good condition following testing with both Coating I and II. There was some abrasion of the coating on shaft number 22, probably caused by the excessive bearing debris. Results of the hydraulic fluid contamination tests, shown in Tables 14 and 15, indicate no significant difference in total cycles completed by X1461 liner against the two coatings. The shafts exhibited significant abrasion in the coating for shafts coated with both Coating I and II. Coating II was almost completely worn off on shafts 45 and 46 in which the total wear exceeded the failure criteria of 0.0040".

Table 12. Results of 69.4 ksi Oscillation Wear Tests For Coating I versus X1461 Liner, Dry Condition.

Test Shaft Number	Fit Between Bearing and Test Shaft (in)	Sanded (yes or no)	Total Wear (in)	Total Cycles Completed
8	0.0040	no	0.0048	1200
22	--	yes	0.0040	125
28	0.0003	yes	0.0041	760
29	0.0005	no	0.0034	1000
30	0.0004	yes	0.0035	1580

Table 13. Results of 69.4 ksi Oscillation Wear Tests for Coating II versus X1461 Liner, Dry Condition.

Test Shaft Number	Fit Between Bearing and Test Shaft (in)	Sanded (yes or no	Total Wear (in)	Total Cycles Completed
44	--	yes	0.0067	2200
48	--	yes	0.0060	1800
49	--	yes	0.0063	3175

Table 14. Results of 69.4 ksi Oscillation Wear Tests for Coating I versus X1461 Liner with fluid contamination.

Test Shaft Number	Fit Between Bearing and Test Shaft (in)	Sanded (yes or no)	Total Wear (in)	Total Cycles Completed
9	0.0027	no	0.0046	1180
12	0.0036	no	0.0049	1100
31	0.0003	yes	0.0048	1275

Table 15. Results of 69.4 ksi Oscillation Wear Tests for Coating II versus X1461 Liner with fluid contamination.

Test Shaft Number	Fit Between Bearing and Test Shaft (in)	Sanded (yes or no)	Total Wear (in)	Total Cycles Completed
45	--		0.0060	7000
46	--		0.0087	2600
47	--		0.0042	2000

Figure 11. Indicated wear for 69.4 ksi test for Coating I versus X1461 liner, Dry Condition.

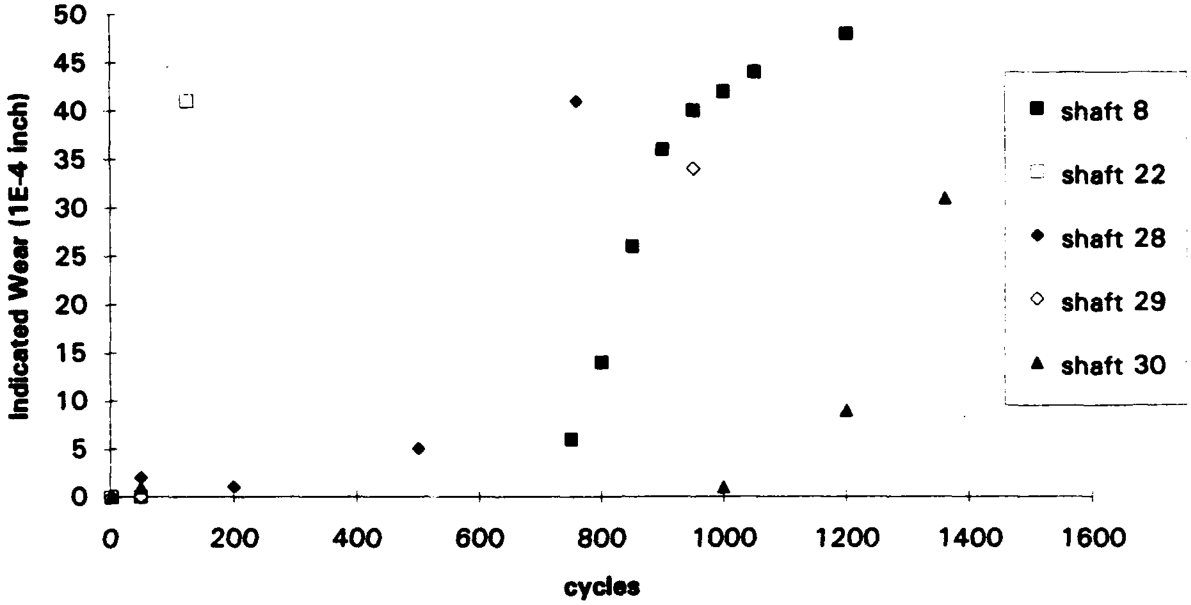


Figure 12. Indicated wear for 69.4 ksi test for Coating II versus X1462 liner, Dry Condition.

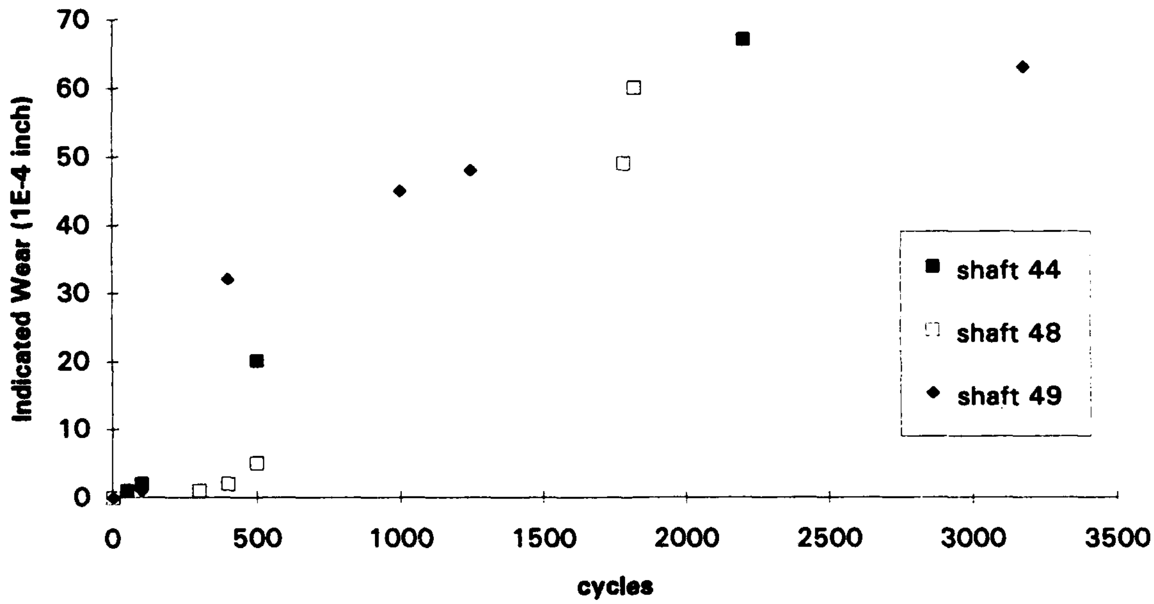


Figure 13. Indicated wear for 69.4 ksi test for Coating I versus X1461 liner with hydraulic fluid contamination.

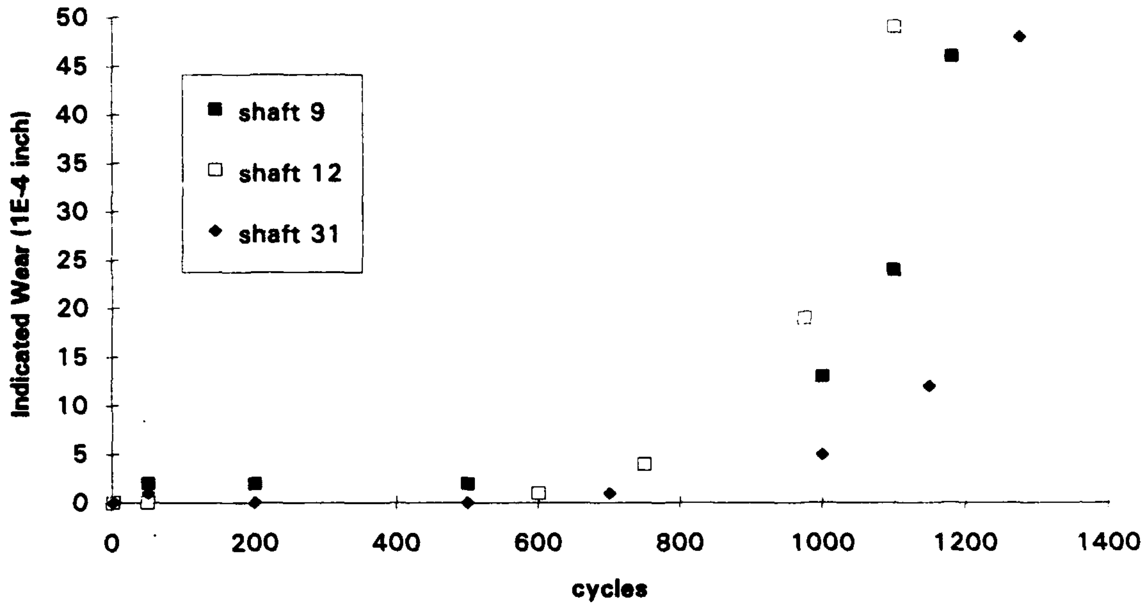
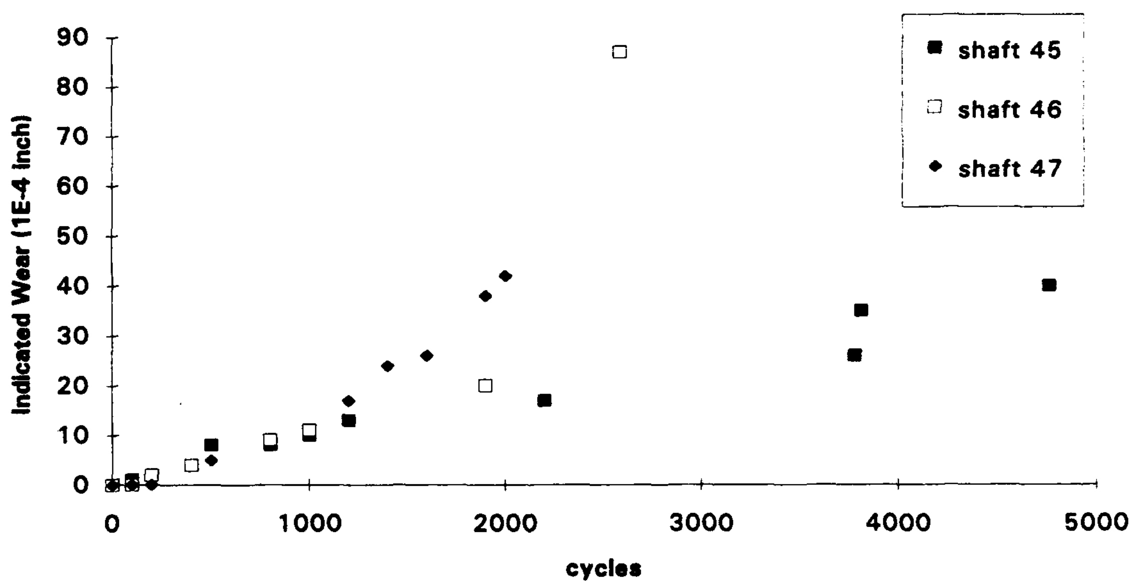


Figure 14. Indicated wear for 69.4 ksi tests for Coating II versus X1461 liner with hydraulic fluid contamination.



CONCLUSIONS

Based upon the results of constant load/constant speed bearing wear tests performed on shafts coated with the original coating formulation and shafts coated with the alternate coating subjected to forced pigment sedimentation, it is concluded that there is no significant difference in the performance between the original and alternate coatings. Therefore it is concluded that the alternate DeSoto coating subjected to the forced pigment sedimentation is suitable for use on the F-14 wing lug.

Bearings constructed with the X1200S liner performed significantly better than those constructed with the X1461 liner in both dry and hydraulic fluid contaminated condition regardless of which coating was used. Results of these tests also indicate that the application technique of the coating is critical in the coating performance. The coating should be applied by spraying several thin coats to achieve a thickness of 0.8 to 1.5 mils as specified in Appendix A rather than a single coat.

RECOMMENDATIONS

Based upon the results of the laboratory tests it is recommended that the alternate DeSoto fuel tank coating and the centrifugation process specified in Appendix A be approved for use on the F-14 wing lug.

To achieve the desired wear characteristics of the wing pivot bearing and protection of the wing lug, the coating should be applied by spraying several thin coats to achieve a thickness of 0.8 to 1.5 mils.

APPENDIX A

F-14 Wing Lug Coating Centrifugation Method

Material: Integral Fuel Tank Coating, MIL-C-27725B, Type II, Class B manufactured by DeSoto Inc., Berkeley, CA. Product designations - base component 832-707, curing solution 910-710, and thinner 020-707. Mix ratio of components - 4 parts by volume of base, 1 part of curing solution, and 4 parts thinner.

Procedure:

1. Stir and shake base material until uniform.

2. Thoroughly mix base, curing solution and solvent in a 4:1:4 ratio.

3. Let material stand covered at ambient conditions for 1 hour.

4. Re-stir material and pour into centrifuge tubes.

5. Centrifuge for 30 to 60 minutes at 1000 rotations per minute (RPM). At this time there should be a clear indication of pigment settling at the bottom 50% of the mixture.

6. Decant or pipette of the top 50% (resin-rich layer) and filter this portion through a 240 mesh silk cloth.

7. Properly discard remaining 50% (pigment rich layer) of material.

8. Spray apply to produce a dry coating (0.8 to 1.5 mils). This is best accomplished by spraying thin coats.

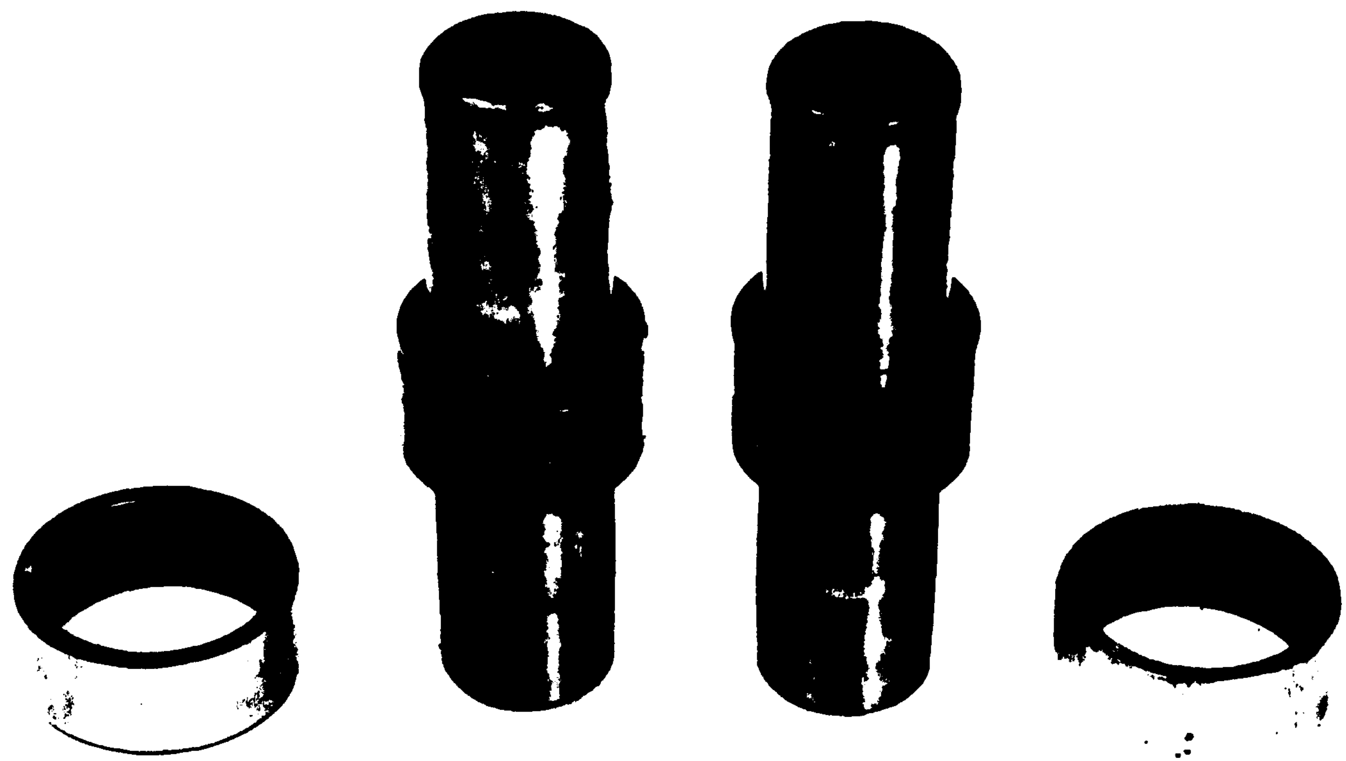
9. Allow wing lug to dry at ambient conditions for a minimum of 3 hours prior to heat curing.

10. Subject applied coating to heat cycle as follows:

    3 hours at 70°F
    30 minutes at 205°F
    40 minutes at 335°F
    4 hours at 310°F

APPENDIX B

Photograph of Test Specimens for the F-14 Wing Lug Coating



From Left to Right: (a) tested stainless steel bearing with liner bonded to the inner diameter; (b) tested titanium sleeve, coated with polyurethane on outer diameter, bonded to a stainless steel shaft; (c) untested stainless steel bearing with liner bonded to the inner diameter; and (d) untested titanium sleeve, coated with polyurethane on outer diameter, bonded to a stainless steel shaft.

APPENDIX C

Liner Stress Calculations for Cylindrical Bearings

1. Equation for the maximum liner stress in a cylindrical bearing:

$$P_{max} = \frac{1.272F}{D(L-4t)}$$ [1]

where

F = Force
D = outer diameter
L = bushing length
t = liner thickness

2. Initial NAWC-AD Warminster tests:

F = 16,000 lbs
D = 1.000"
L = 0.500"
t = 0.012"

$$P_{max} = \frac{1.272(16000)}{1.000(.5000-4(.012))} = 45{,}027\text{psi}$$

3. To achieve the maximum stress from the Grumman 9/9A test the load was increased to 18,000 pounds and a new bearing length was determined:

P_{max} = 69458 psi
F = 18,000 lbs
D = 1.000"
t = 0.012"

$$L = \frac{1.272F}{D(P_{max})} + 4t = \frac{1.272(18{,}000)}{1.000(69458)} + 4(0.012) = 0.378 \text{ inch}$$

4. Therefore the test parameters to achieve maximum liner stress are:

F = 18,000 lbs
D = 1.000 inch
L = 0.380 inch

[1] William A.Kuhn and F.M. Drilling, "How to design with PTFE lined bearings", Power Transmission Design, May 1969.